NON-INVASIVE EARLY DIAGNOSIS OF DEEP VEIN THROMBOSIS

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ABSTRACT

Deep Vein Thrombosis (DVT) is a blood clot that forms in deep veins which commonly occur in lower limb or thigh. The blood clot blocks deep vein and can travel to lung and block pulmonary arteries. This condition will cause fatal Pulmonary Embolism (PE). DVT can be diagnosed using non-invasive technique such as ultrasonography. One of the factors that cause the deep vein thrombosis occurs is the behaviour of vein valve. Therefore, the movement of vein valve needs to track to make further analysis of its behaviour for early detection of Deep Vein Thrombosis system. The aim of this project is to track the vein valve movement for early diagnosis of DVT. Distance between two nearest pixels with value 1 and reference line is proposed to be the method to track vein valve movement. The idea of this technique is the smallest distance of nearest pixels to reference line means the vein valve is closed. The distance for each differencing frame is plotted to see the sequence of distance pattern of vein valve closure. Baseline is created via observation (eye) method for experimental programme. The percentage difference between vein valve closure times of result from automatic tracking and baseline is 3.57%. Therefore, it showed that the proposed method is applicable and able to tracking the vein valve movement.

ABSTRAK

Deep Vein Thrombosis (DVT) adalah pembentukan darah beku yang biasa berlaku di bahagian bawah badan atau peha. Darah beku boleh menyebabkan saluran darah tersumbat dan boleh bergerak ke paru-paru dan menyebabkan arteri pulmonari tersumbat. Keadaan ini boleh menyebabkan *Pulmonary Embolism* (PE). DVT boleh didiagnosis menggunakan non-invasif teknik seperti ultrasonografi. Salah satu faktor yang menyebabkan *Deep Vein Thrombosis* adalah tingkah-laku injap vena. Oleh sebab itu, terdapat keperluaan untuk pergerakan injap vena dijejaki untuk menjalankan analisis berkaitan tingkah-lakunya bagi sistem pengesanan awal bagi *Deep Vein Thrombosis.* Projek ini bermatlamat untuk mengesan pergerakan injap vena bagi pengesanan awal DVT. Jarak antara dua pixel yang berdekatan dengan garisan rujukan adalah dicadangkan bagi kaedah untuk mengesan pergerakan injap vena. Idea bagi teknik ini adalah jarak yang paling pendek bagi pixel yang berdekatan dengan garisan rujukan bermaksud injap vena tertutup. Jarak bagi setiap perbezaan kerangka akan diplotkan untuk meneliti urutan corak jarak bagi masa penutupan injap vena. Data asas diwujudkan dengan menggunakan kaedah observation (mata) bagi membuat perbandingan data dengan hasil eksperimen. Perbezaan peratusan masa penutupan injap vena antara kaedah pengesanan automatik dan data asas adalah 3.57%. Oleh itu, ia menunjukkan bahawa kaedah yang dicadangkan dapat mengesan pergerakan injap vena.

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DVT	Deep Vein Thrombosis
PE	Pulmonary Embolism
VTE	Venous Thromboembolism
VDUS	Venous Duplex Ultrasound
CDI	Colour Doppler imaging
RF	Radio Frequency
CLAHE	Contrast-Limited Adaptive Histogram Equalization
SNR	Signal to Noise Ratio
PSNR	Peak Signal to Noise Ratio
MSE	Mean Square Error
PSO	Particle Swarm Optimization
CCA	Common Carotid Artery
SRAD	Speckle Reducing Anisotropic Diffusion
OD&T	Object detection and tracking
ROI	Range of Interest

CHAPTER 1

INTRODUCTION

1.1 Introduction

Deep Vein Thrombosis (DVT) is a blood clot that forms in deep veins which commonly occur in lower limb or thigh. The blood clot blocks deep vein and can travel to lung and block pulmonary arteries. This condition will cause fatal Pulmonary Embolism (PE). Common symptoms of DVT are leg swelling or redness, thigh pain or unilateral calf [1].DVT, PE or combination is broader term that refers as Venous Thromboembolism (VTE) [2]. Figure 1.1 illustrates the concept of Pulmonary Embolism and Deep Vein Thrombosis.

In United State, from 250 000 to 2 million estimated incidence of VTE cases per year [3]. Almost, two-thirds present with DVT symptoms such as calf pain or swelling, while one-thirds present with PE symptoms such as breath difficulty and chest pain [4]. Cases increases with age, growing exponentially from less than 5 per 100,000 per year for under 15 age group to over 500 per 100,000 per year for over 80 years age group [4].

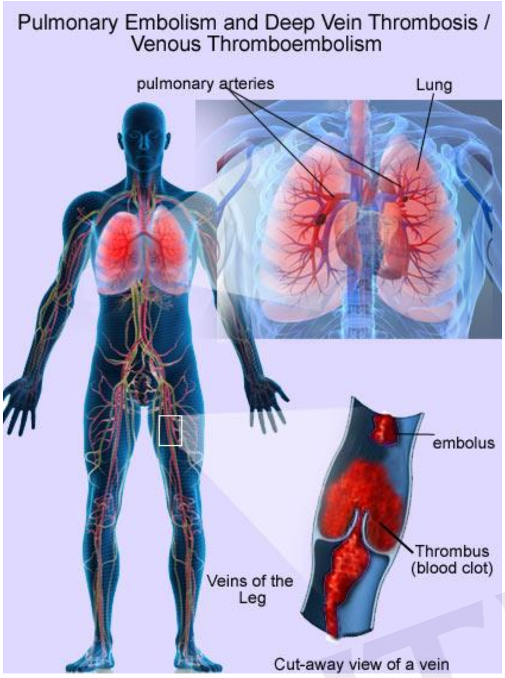

Figure 1.1: Pulmonary Embolism and Deep Vein Thrombosis.[5]

Conventionally, DVT has been diagnosed by contrast venography. This method allows tremendous visualisation of the venous system and identification of both distal and proximal DVT but has limitations. The intravenous contrast usage may be unsafe for pregnancy patient, may lead to renal failure or known allergy, the complex and difficult procedure, expensive, needs professional explanation, and frequently uncomfortable for the patient. All those limitation has led to the exploration for cheaper, simpler, non-invasive tests for DVT [2].

One of the factors that contribute to DVT is deep vein valve insufficiency. Deep vein is travel deep within the muscle of the leg. The popliteal vein valve is located at the level of the groin, near the middle of the thigh, behind the knee and in the smaller veins in the calf. The healthy vein valves control blood flow direction towards the heart. Valvular reflux occurs when valves not competent or unhealthy which allows blood to flow in the reverse direction [6].

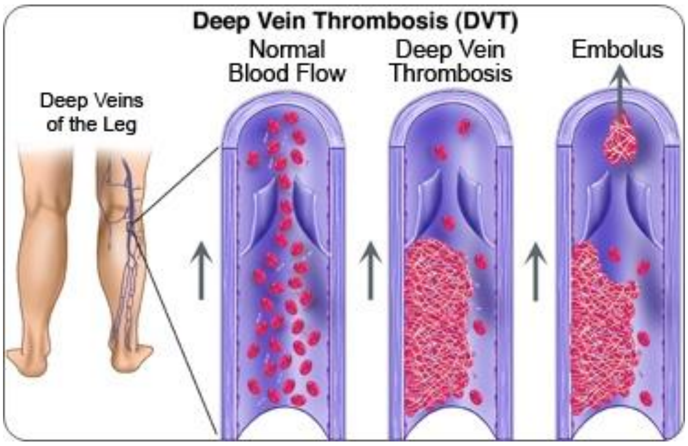

Figure 1.2: Example of incompetence of vein valve [7]

Many researches have been done to study the diagnosis and treatment of patients with high risk of developing VTE. However, there is less research has been done that focus on early diagnosis of DVT especially on deep vein valve behaviour. Therefore, this project will focus on detection and tracking vein valve movement on deep vein ultrasound images (B-mode image) which will contribute to further research on early diagnosis of DVT.

1.2 Problem Statement

The efforts to prevent from VTE diseases are important as the impact of VTE disease severe to the patients. However, there is less research has been done that focus on early diagnosis of DVT. Therefore, there is a need to research the area on early diagnosis of DVT for prevention of DVT.

One of the factors that cause the DVT occurs is the behaviour of venous valve. The patient with DVT disease have incompetent venous valve. Thus, the movement of vein valve need to be tracked to investigate the valve competency for early detection of Deep Vein Thrombosis.

Currently, the diagnosis of Deep Vein Thrombosis (DVT) uses ultrasonography method. The problem that always occurs during interpretation of ultrasound images are degradation of the fine details and edge definition due to speckle noises existence. This problem leads wrong diagnosis. Therefore, the excellent image processing method needs to propose to avoid this problem and help to improve the research.

1.3 Aim and Objectives

The aim of this project is to track the vein valve movement for early diagnosis of DVT. To achieve the aim of this project, the following objectives have been set up:

1. To develop the valve movement tracking algorithm based on image processing technique.
2. To validate the proposed algorithm via a series of experiments.
3. To measure the frequency of venous valve movement of ultrasound images.

1.4 Scope of Project

The scopes of the project are:

1. To create an algorithm to detect and tracking popliteal vein valve movement on ultrasound image created by B-Mode images.
2. To use MATLAB® software for the suggested algorithm development.

1.5 Rationale and Significant

The impact of this project is to help the researcher to study the behaviour of venous valve of deep vein for early diagnosis of DVT. The project is intended to develop specific method and algorithm for tracking venous valve movement automatically.

The significant of the research is to study the best possibility method for image enhancement for ultrasound images and the tracking venous valve movement.

1.6 Project Outline

The thesis comprise in 5 chapters together including Chapter 1 is on Introduction, Chapter 2 is Literature Review, Chapter 3 is Methodology, Chapter 4 discuss result and discussion followed by last chapter which is Conclusion.

Chapter 1 will discuss the introduction of the thesis by outlining the overview of the project. It will start with problem statement, objectives of the project, the project scope and the impact and significant of the project.

In Chapter 2, it reviews the previous works from thesis, journals, conference paper and experiments that related to the project. The literature review includes Deep Vein Thrombosis Diagnosis, Venous Valve Cycle, Image Processing and Object Detection and Tracking.

Chapter 3 represents the research methodology of the project. The step by step procedure used to run the project will be explained in details. It will also include the flowchart of processes involved in software development of entire project.

Chapter 4 will contain the simulation results and its respective analysis. The result will be discussed and explained with the aid of diagrams. The comparison of every finding will be explicated in detail.

In Chapter 5, it will summarize the overall project and suggest the future recommendation to be improved in the research field.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter present the concept of ultrasound imaging, noise occur on its images and the theory of venous valve closure cycle. Image processing for image enhancement, noise filtering, segmentation and object detection and tracking also has been discussed this chapter.

2.2 Deep Vein Thrombosis (DVT) Diagnosis

DVT can be diagnosed using non-invasive technique such as ultrasonography include assessment of venous condition, use grey-scale image to visual the blood clot in real-time, and recognise areas of venous thrombosis by using Doppler, colour flow and power Doppler imaging [4].

One of the techniques is venous duplex ultrasound (VDUS) [4]. This technique is combination of two components which are colour Doppler imaging (CDI) and brightness-mode (B-mode) compression maneuverers. CDI is applied to evaluate blood circulation while B-mode is used to detect 2D structure image of vein to identify blood clot presence.

Basically, ultrasound imaging system uses sound waves with high frequency as imaging method. This ultrasound device is non-ionized system therefore it is quite popular for non-invasive diagnostic device. The device is capable to display structure and movement of the human's internal organs including blood vessels. This imaging system consists of three basic types of data which are Radio Frequency (RF) signals, B-Mode images and envelope-detected signals. In medical application, there are many available ultrasound modes such as A mode, B-mode, colour Doppler and Continuous Doppler [9].

The ultrasound image contains noise such as speckle noise. This noise degrades the fine details and edge definition of ultrasound images [9]. Thus, it is difficult to detect small and low contrast lesions in body due to contrast resolution limit by the noise. All developed noise is due to air gap between ultrasound transducer and body during imaging process, beam forming process and stage of signal processing. Therefore, image enhancement and noise filtering process need to be applied for further analysis and diagnosis of the ultrasound images.

2.3 Venous Valve Cycle

A consistent pattern of flow event is identified in healthy femoral and great saphenous vein when the blood passes through the valve station. Valve cycle, the time period between two consecutive closures of the valve is physiological process of flow events and movement of the valve leaflets combination [10].

The valve cycle is divided into four phases which are opening phase, equilibrium phase, closing phase and closed phase [10]. These four phases of valve cycle is illustrated in Figure 2.1.

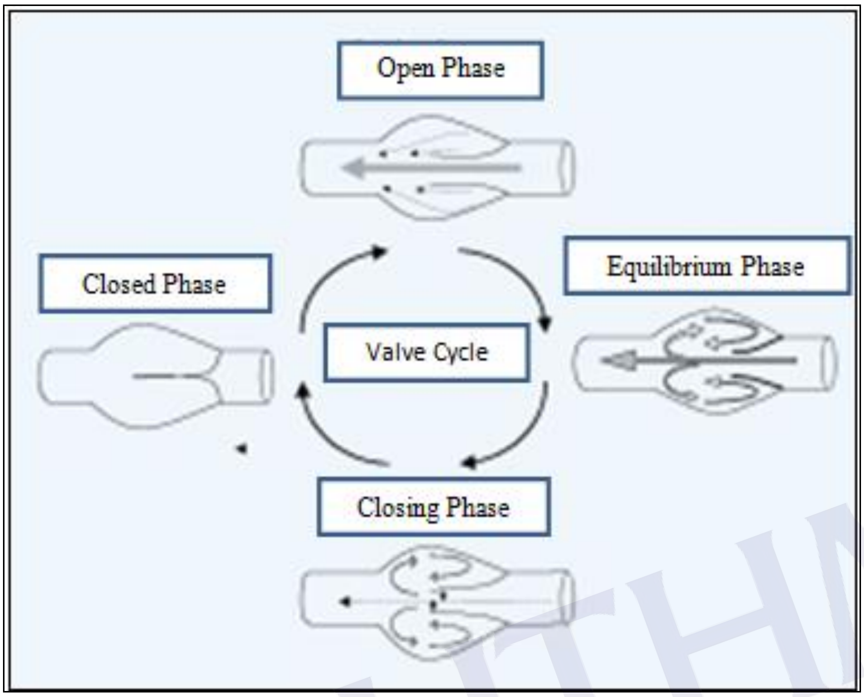

Figure 2.1: The valve cycle [10]

Table 2.1 shows the information during each phase. The position of the body influenced the duration valve cycle. In horizontal position, the duration of the vein cycle approximately 1.7 to 1.8 seconds. The frequency of the valve cycle is approximately 34.2 cycles per minute [10].

Table 2.1: The four phases of the venous valve cycle [10][11]

Phase	Information
Opening phase	Which the cusps move from the closed position toward the vein wall Lasts on average 0.27 seconds
Equilibrium phase	Which the valves are no longer opening, but remain suspended open undergoing oscillation or fluttering in the blood flow Lasts on average 0.65seconds
Closing phase	Which the valves move synchronously towards the centre of the vein Lasts on average 0.41 seconds
Closed phase	Which the valve remains closed Lasts on average 0.45 seconds

2.4 Image Processing

Basically, image enhancement is about image processing to get better and accurate image to correctly diagnose by doctors. The examples of image enhancement's techniques are noise filtering, contrast stretching and histogram modification [12]. Noise filtering is used to clean the needless information from an image by using any filter type such as median filter or mean filter. Contrast stretching is technique can be used for image that has homogenous histogram. The technique expanses the narrow range to the entire of the existing dynamic range. Histogram is important to image processing as it provides the characteristic of image such as intensity and pixels. The modification of histogram can be used to change the image's characteristics. One of the histogram modification techniques is histogram equalization which redistributes pixel values to create flat histogram. Contrast-Limited Adaptive Histogram Equalization (CLAHE) is one of histogram equalization [13].

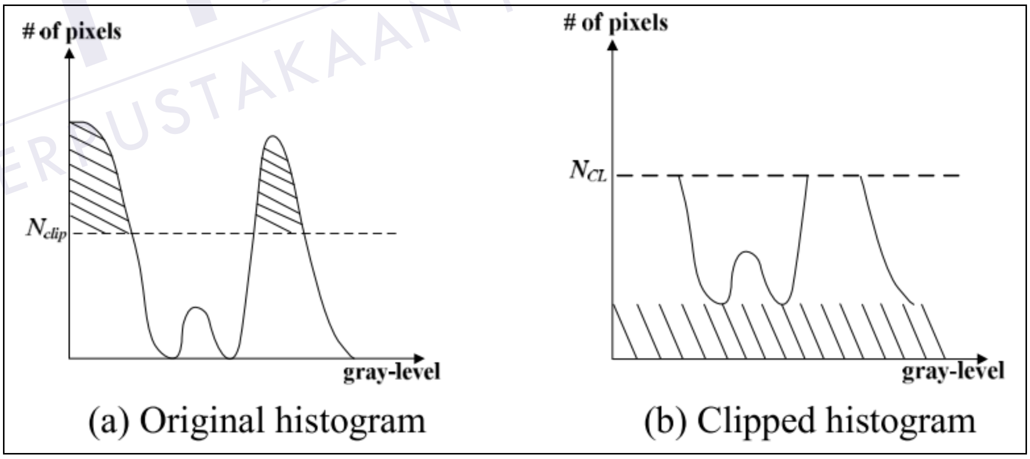

Figure 2.1 : Histogram modification by using CLAHE method [14].

The quality of filtered images can be evaluate quantitatively with Signal to Noise Ratio (SNR), Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Root Mean Square Error [15][16].

$$SNR = 10.\log_{10} \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(x_{i,j}^{2} + y_{i,j}^{2}\right)}{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(x_{i,j}^{2} - y_{i,j}^{2}\right)^{2}} \qquad \text{---- (2.1)}$$

$$PSNR = 20.\log_{10}\left(\frac{g^{2}{}_{\max}}{MSE}\right) \qquad \text{---- (2.2)}$$

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(x_{i,j}^{2} - y_{i,j}^{2}\right)^{2} \qquad \text{---- (2.3)}$$

$$RMSE = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(x_{i,j}^{2} - y_{i,j}^{2}\right)^{2}} \qquad \text{---- (2.4)}$$

Where M,N is size of tested image, x is filtered image, y is input image and g is maximum intensity of unfiltered image.

In Vanithamani [15], modified Hybrid Median Filter is proposed in order to reduce speckle noise. In moving window of 5x5 pixel neighbourhood, the maximum value of 45° neighbours creating an “X” form and median value of 90° neighbours creating an “+” form are compared with the central pixel to get median value. Then, the value will save as the new pixel value. The quality of image filtered with this method is compared with other filter such as Lee Filter, Hybrid Median Filter and so on. As result, the proposed filter capable to reduce speckle noise efficiently compared to others filter without blurring the edges of image.

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